Optimization of A Small Scale Dual-Axis Solar Tracking System Using Nanowatt Technology

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***Abstract*—The solar module will be positioned first in North, East, West or South. Then, the PV array will automatically search and stop at the highest current gained by the solar cell. This will occur every 30 minutes from 0600H up to 1800H. In these positions the values of current, voltage and power were measured. The design focuses on different applications in a small farm setting with fan, incubator, aquarium pump motor and lightning. In essence, highlighted are the technical concepts of solar energy for electricity generation.**

***Index Terms*—solar energy, nanoWatt technology, solar tracker**

I. INTRODUCTION

The harnessing and utilization of renewable energy (RE) comprises a critical component of the government's strategy to provide energy supply for the country. Currently, the large-scale use of photovoltaic cells is not economically competitive in the market of electricity generation. The current plans and programs of the Philippines are crafted to respond to the challenges that are confronting the energy sector at present and usher the change in the landscape of the country's energy future. [1]

To reduce the cost of the energy you want to capture is the main reason to use a solar tracker. This additional output or "gain" can be quantified as a percentage of the output of the stationary array. Gain varies significantly with latitude, climate, and the type of tracker you choose—as well as the orientation of a stationary installation in the same location. Climate is the most important factor to move the tracker. [2] Solar trackers add to the efficiency of the system, reducing its size and the cost per KWH. [3] Full tracking or dual-axis trackers move on two axes to point directly at the sun, taking maximum advantage of the sun's energy while single-axis trackers follow the sun accurately enough that their output can be very close to full tracking. [4] [5]

II. DESIGN AND LAY-OUT

A. Objectives

The general objective of this project is to be able to design a 60W photovoltaic solar energy panel and to determine the optimum intensity of light to photovoltaic array. Specifically, this project aims to determine the amount of voltage, current and electrical power generated by solar-module as a facade element in relation to its tilt angle and orientation; to provide electricity through photovoltaic solar energy in a small farm with incubator, lamp and aquarium pump motor; to design a system where all devices are dependent to the electrical energy generated by the solar panel; to automatically align the solar panel in the best possible angle to generate solar energy and to properly allocate the electrical power generated by PV array thru lamp scheduling.

B. Design

This paper will only discuss the benefits of using solar panels as an alternative source of energy and how it can be a practical energy source. This research will not deal with other renewable sources of energy such as wind energy and the non-renewable sources of energy like fossil fuel energy. For prototype purpose, the machine is not protected against rain or storm. The load scheduling algorithm will focus only on the application of lamp, whereas, it will be activated only from 1800H – 0600H.

Figure 1. Project prototype

Fig. 1 illustrates the actual prototype of the project which has the following features: (a) 12/24Vdc Solar Charge Controller that protects the system from overload, short circuit, under-voltage and over-charge. Temperature ranges from -20 degree Celsius up to 60 degree Celsius; (b) Real time keeping chip, to automatically determine the optimum amount of sunlight every 30minutes from 0600H-1800H; (c) Dual functionality of tact switches: manual tilting of the motor and modification of the clock thru 16x2 LCD; (d) Enhanced nanoWatt Technology that reduces power consumption during operation [6]; (e)

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Three versatile 12Vdc outputs: OUT1- activated only from 1800H–0600H (good for street lamps) OUT2/OUT3–activated the whole day (good for incubator lamp, aquarium pump motor, fan); (f) Dual H-Bridge Motor Driver for Direction Motor and Tilting Motor and (g) Enhanced applications of Optical Sensors.

III. I/O Connections

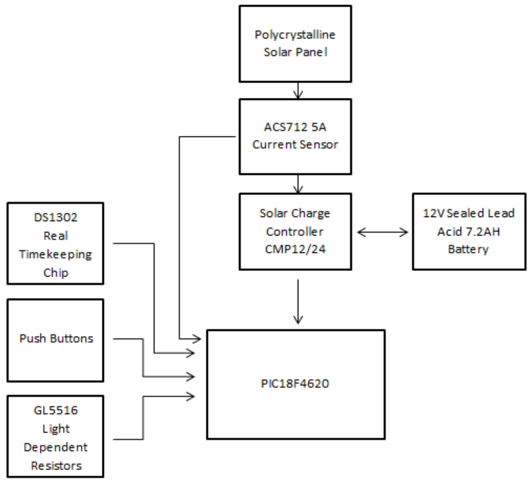

Figure 2. PIC 18F4620 inputs

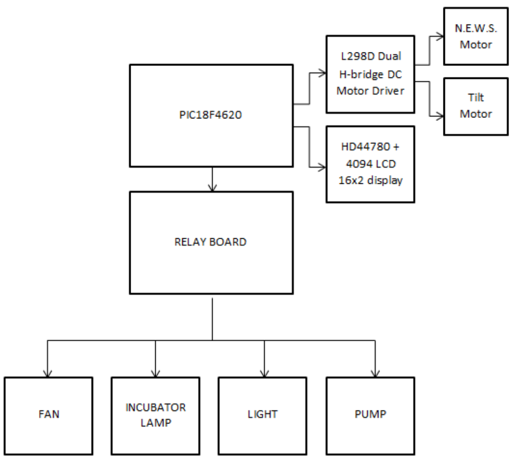

Figure 3. PIC 18F4620 outputs

Fig. 2 and Fig. 3 show the solar charge controller that can adjust the charge current and decide if to supply the loads electricity according to the voltage of battery. This solar charge controller can protect the system from overload, short circuit, under-voltage, and over-charge. Temperature ranges from -20 degree Celsius up to 60 degree Celsius.

Real time keeping chip will ensure that the system will search for optimum solar energy every 30 minutes from 0600H - 1800H. There are two dc motors connected to the microcontroller, the NEWS motor: to determine the maximum amount of solar energy from North, East, West or South; and the tilt motor.

For simulation purpose, and aside from the motor and LCD display, there are four major outputs dependent to the solar source: fan, lamp, incubator lamp, led light and air pump motor for the aquarium.

IV. Analysis of Results

The experiment was conducted in the farm of Cavite State University-Indang, Cavite-Philippines. The main motivation of this experiment is to provide electricity in a farm and to determine the optimum amount of sunlight. CVSU's farm is a perfect place to simulate or to test the machine in an actual farm setting. Nestled in the hidden side of Indang, Cavite, the property is built near the river surrounded with different fruit-bearing plants and animals.

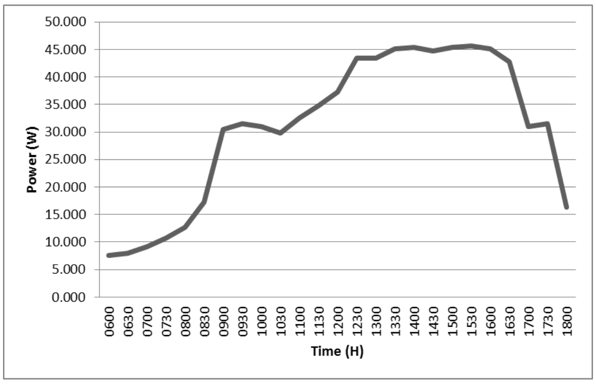

Figure 4. March 25, 2013 power reading

Fig. 4 show the power reading of the project. It is evident, therefore, that the optimum amount of light is in between 1300H-1700H. The weather for this day was mostly clear with thin clouds, with a day of reserve energy of about an hour. The results of the test show that a timing device would improve the efficiency of the prototype.

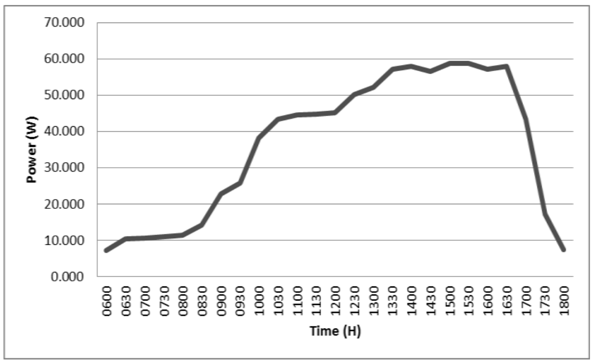

Figure 5. April 1, 2013 power reading

Fig. 5 shows the impact of the prototype on April 1, 2013. The maximum intensity of light was observed at around 1300-1700H. The plot in Fig. 3 demonstrates the rising and falling solar insolation values in April 1, 2013. The setup was incorporated the same way as the previous March 25, 2013.

Fig. 6 was observed on April 3, 2013 where the highest temperature, according to DOST-PAGASA, was experienced.

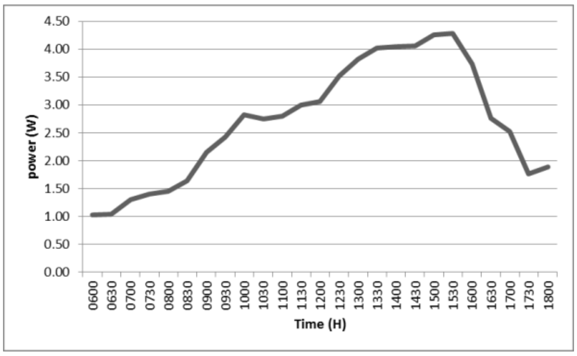

Figure 6. April 3, 2013 power reading

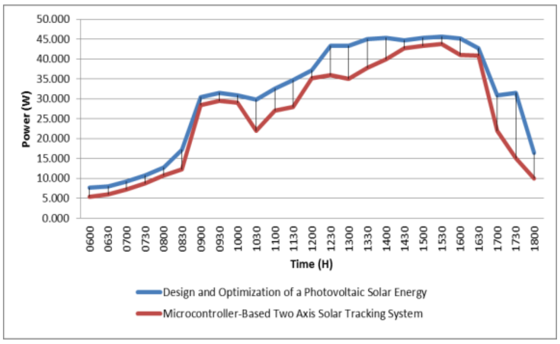

Figure 8. Comparison to microcontroller-based two axis solar tracking system

Data shows that from all 3 tests, the highest voltage and current gained at around 1530H. the results of the tests evaluated the different variations that could be considered in determining the optimum quality or intensity of sunlight in relation to its tilt angle.

He following test shows the difference between the fixed solar panel versus the solar tracker conducted last April 27, 2013. However, due to the weather condition or cloudy weather, a considerable drop of power was observed. In this particular test, a 50 Watt Solar panel was adjusted to 20 Watt solar array.

A two-axis tracker offers a great power increase over a fixed solar panel, the solar tracker made incorporates the use of DC motor for economic purpose.

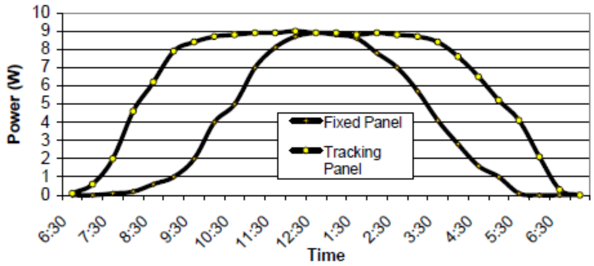

Figure 7. Fixed panel versus tracking panel

Quite simply having two test subjects carried out provides the necessary comparison between the fixed and auto-tracker. The first scenario involved removing the panel from the tracker and laying it in a flat orientation. In this particular test, the tracking panel produces more power than the ordinary fixed panel.

A similar study was conducted by Prof. Richard Ramos of the Future University; it shows the difference of his solar tracker compared to the author's design and concept. In his paper, the solar tracking system will occur every 30 minutes with a fixed angle of 15^{o}, 30^{o}, 45^{o}, 60^{o}, 75^{o} and 90^{o}. He uses a parabolic reflector to trace the sun the whole day from 0600H up to 1800H. [7]

The test was guided around March 2011, comparing it to the author's data guided around March 2013. Both experiments showed the highest intensity of sunlight between 1500H and 1630H. However, Design and Optimization of a Photovoltaic Solar Energy has the most power gained due to its design and application.

V. Recommendation

For further improvement, an integration of wireless networks can be implemented. According to the IEEE paper of Oscar Lapena, *et. al.*, "Using wireless networks can lead to a maximum central-processing-unit duty cycle of 6% and frees the microcontroller to be used in the remaining tasks of the autonomous sensor, such as sensing, processing, and transmitting data. In order to reduce power consumption, dynamic power management techniques were applied, which implied the use of predictive algorithms. In addition, the measurement and acquisition of the output current and voltage of the PV panel, which increase circuit complexity, was avoided." [8]

This study can also integrate an Altera Nios II configurable embedded processor to perform solar tracking. This integration accelerates development while maintaining design flexibility, reduces the circuit board costs with a single-chip solution, and simplifies product testing. The design includes: (1) Balance positioning- A tilt switch prevents the solar panels from hitting the mechanism platform and damaging it or the motor; and (2) Automatic mode- The system receives sunlight onto the cadmium sulphide (CdS) photovoltaic cells where the CdS acts as the main solar tracking sensor. The sensor feeds back to the FPGA controller through an analog-to-digital (A/D) converter. The processor is the main control core and adjusts the two-axis motor so that the platform is optimally located for efficient electricity generation.

Solar radiation data is usually measured in the form of global radiation on a horizontal surface at the concerned latitude. Flat-plate collectors are tilted so that they capture maximum radiation. Since the flat-plate solar collectors are positioned at an angle to the horizontal, it is necessary to calculate the optimum tilt angle which maximizes the amount of collected energy.

VI. Conclusion

The solar still is a relatively inexpensive, low-technology system, especially useful in the rural and remote communities of the developing countries especially in the regions of Mindanao, Philippines. There is equally need for innovation and room for improvement both technically and economically. If properly harnessed, the solar still provides a considerable economic advantage over other applications. Introducing the sun tracking mechanism to a fixed solar still has improved the performance. This means that there is a possibility to improve the performance of this conventional solar still system using sun tracking.

The tilting of the upper dc motor returns to zero before the output occurs, thus, making it as open-loop control system. An open-loop controller is used in the process because of its simplicity and low cost.

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